

RADIO COMMUNICATIONS APPARATUS AND
TRANSMISSION POWER CONTROL METHOD THEREOF

Background of the Invention

5 The present invention relates to a transmission power control method and radio communications apparatus effective for control of transmission power in the cellular CDMA (Code Division Multiple Access) system.

In the CDMA system, a single frequency band is shared by
10 a plurality of users. This results in the fact that a signal from another station acts as an interference wave and degrades the circuit quality of a local station. As a technology to solve this problem, transmission power control is used. Particularly,
As a transmission power control method for following an
15 interference signal that varies instantaneously, a transmission power control method via closed loop is known.

Fig. 12 shows an example of a conventional transmission power control method via closed loop. As shown in Fig. 12, in case a base station and a mobile station communicates with each
20 other, the base station determines a transmission power bit from a radio wave received from the mobile station (S11), inserts the transmission power control bit in a transmission signal, and transmits the resulting signal to the mobile station. The mobile station receives the signal transmitted from the base
25 station, extracts the transmission power bit (S15) and controls

its variable power amplification means according to the instruction of the transmission power control bit (S16).

Similarly, the mobile station determines a transmission power bit from a radio wave received from the base station (S14),
5 inserts the transmission power control bit in the transmission signal, and transmits the resulting signal to the base station. The base station receives the signal transmitted from the mobile station, extracts the transmission power bit (S12) and controls its variable power amplification means according to the
10 instruction of the transmission power control bit (S13).

In case high-accuracy transmission power control is made via an aforementioned conventional transmission power control method, a high-accuracy variable power amplifier is required and high-accuracy control of a variable power amplifier is
15 required. However, an attempt to perform variable power amplification control using a high-accuracy variable power amplifier results in an increased circuit scale and power consumption as well as reduced portability.

20 Summary of the Invention

The invention, in view of the problems, aims at providing a transmission power control method whereby the accuracy of transmission power control is upgraded and lower power consumption and a smaller apparatus design are allowed via a
25 simple configuration, and radio communications apparatus that

uses the control method.

A transmission power control method according to the first aspect of the invention is a transmission power control method for controlling the power to transmit to the distant party, 5 characterized in that the method comprises variable power amplifying steps (S105, S205) for respectively controlling digital-to-analog conversion means provided in the preliminary stage of a modulator for frequency-converting a transmission signal to a signal in the IF band, the means generating an analog 10 baseband signal to be supplied to the modulator, and a plurality of variable power amplification means for variably amplifying the transmission signal modulated by the modulator.

A transmission power control method according to the second aspect of the invention is characterized in that the variable power amplifying steps modify the control ratio of the variable power amplification means and make series or parallel control 15 in the control range.

A transmission power control method according to the third aspect of the invention is characterized in that the method 20 comprises steps of detecting the state of a local station or a distant station (S102, S202) and steps of modifying the control ratio according to the detected state.

A transmission power control method according to the fourth aspect of the invention is characterized in that the method 25 comprises steps of detecting a plurality of states of a local

station or a distant station (S102, S202) and steps of modifying the control ratio by using the fuzzy control rules and fuzzy inference that are based on the plurality of states.

A transmission power control method according to the fifth aspect of the invention is characterized in that the method comprises a step of adaptively modifying the control ratio according to the state of a local station or a distant station.

A transmission power control method according to the sixth aspect of the invention is characterized in that the control sensitivity of each of the plurality of variable power amplification means differs from each other.

A transmission power control method according to the seventh aspect of the invention is a transmission power control method for controlling the power to transmit to the distant party, characterized in that the method comprises voltage control means controlling steps (S104, S204) for controlling a plurality of voltage control means that control a power amplifier for amplifying a transmission signal via separate bias systems.

A transmission power control method according to the eighth aspect of the invention is characterized in that the voltage control means controlling steps modify the control ratio of the voltage control means and make series or parallel control in the control range.

A transmission power control method according to the ninth aspect of the invention is characterized in that the method

TUDV90-202764860

comprises steps of detecting the state of a local station or a distant station (S102, S202) and steps of modifying the control ratio according to the detected state.

A transmission power control method according to the tenth aspect of the invention is characterized in that the method comprises steps of detecting a plurality of states of a local station or a distant station (S102, S202) and steps of modifying the control ratio by using the fuzzy control rules and fuzzy inference that are based on the plurality of states.

10 A transmission power control method according to the eleventh aspect of the invention is characterized in that the method comprises a step of adaptively modifying the control ratio according to the state of a local station or a distant station.

15 A transmission power control method according to the twelfth aspect of the invention is characterized in that the control sensitivity of each of the plurality of variable power amplification means differs with each other.

Radio communications apparatus according to the thirteenth aspect of the invention is radio communications apparatus equipped with the transmission power control feature for controlling the power to be transmitted to the distant station, characterized in that the apparatus comprises variable power amplification means including a digital-to-analog conversion means (DAC 17) provided in the preliminary stage of a modulator (modulator 16) for frequency-converting a transmission signal

to a signal in the IF band, the means generating an analog baseband signal to be supplied to the modulator and a plurality of variable power amplifiers (variable amplifiers 14, 15) for variably amplifying the transmission signal modulated by the modulator, 5 and variable power amplification control means (variable power amplification control means 18) for controlling the variable power amplification means.

Radio communications apparatus according to the fourteenth aspect of the invention is characterized in that the 10 variable power amplification control means modifies the control ratio of the variable power amplifier and make series or parallel control in the control range.

Radio communications apparatus according to the fifteenth aspect of the invention is characterized in that the apparatus 15 has state detection means (state detection means 23) for detecting the state of a local station or a distant station and modifies the control ratio according to the detected state.

Radio communications apparatus according to the sixteenth aspect of the invention is characterized in that the apparatus 20 modifies the control ratio based on the fuzzy control rules and fuzzy inference.

Radio communications apparatus according to the seventeenth aspect of the invention is characterized in that the apparatus adaptively modifies the control ratio according 25 to the state of a local station or a distant station.

Radio communications apparatus according to the eighteenth aspect of the invention is characterized in that the control sensitivity of each of the plurality of variable power amplification means differs from each other.

5 Radio communications apparatus according to the nineteenth aspect of the invention is radio communications apparatus equipped with the transmission power control feature for controlling the power to be transmitted to the distant station, characterized in that the apparatus comprises a power amplifier
10 (power amplifier 13) for amplifying a transmission signal, a plurality of voltage control means (first and second voltage control means 19, 20) for controlling the power amplifier via separate bias systems, and control means for controlling voltage control means (control means for controlling voltage control
15 means 21) that controls the voltage control means.

Radio communications apparatus according to the twentieth aspect of the invention is characterized in that the control means for controlling voltage control means modifies the control ratio of the voltage control means and make series or parallel
20 control in the control range.

Radio communications apparatus according to the twenty-first aspect of the invention is characterized in that the apparatus has state detection means (state detection means 23) for detecting the state of a local station or a distant station
25 and modifies the control ratio according to the detected state.

09074052

Radio communications apparatus according to the twenty-second aspect of the invention is characterized in that the apparatus modifies the control ratio based on the fuzzy control rules and fuzzy inference.

5 Radio communications apparatus according to the twenty-third aspect of the invention is characterized in that the apparatus adaptively modifies the control ratio according to the state of a local station or a distant station.

10 Radio communications apparatus according to the twenty-fourth aspect of the invention is characterized in that the control sensitivity of each of the plurality of variable power amplification means differs from each other.

15 According to the invention, via a configuration for respectively controlling digital-to-analog conversion means provided in the preliminary stage of a modulator for frequency-converting a transmission signal to a signal in the IF band, the means generating an analog baseband signal to be supplied to the modulator, and a plurality of variable power amplification means for variably amplifying the transmission signal modulated by the modulator, it is possible to upgrade 20 the accuracy of transmit power control and assure lower power consumption and smaller size of apparatus via a simple configuration

Fig. 1 is a flowchart showing the principle of transmission power control according to first embodiment;

Fig. 2 is a flowchart showing an example of transmission power control according to first embodiment (case 1);

5 Fig. 3 is a flowchart showing an example of transmission power control according to first embodiment (case 2);

Fig. 4 is a flowchart showing an example of transmission power control according to first embodiment (case 3);

10 Fig. 5 is a flowchart showing an example of transmission power control according to first embodiment (case 4);

Fig. 6 is a flowchart showing an example of transmission power control according to first embodiment (case 5);

Fig. 7 is a flowchart showing an example of transmission power control according to second embodiment (case 1);

15 Fig. 8 is a flowchart showing an example of transmission power control according to second embodiment (case 2);

Fig. 9 is a flowchart showing an example of transmission power control according to second embodiment (case 3);

20 Fig. 10 is a flowchart showing an example of transmission power control according to second embodiment (case 4);

Fig. 11 is a block diagram showing an example of radio communications apparatus according to third embodiment of the invention;

25 Fig. 12 is a flowchart showing the principle of transmission power control according to the related art.

Detailed Description of the Preferred Embodiments

Embodiment of the invention will be described referring to the drawings.

5 (Embodiment 1)

Fig. 1 is a flowchart showing the procedure of the transmission power control method according to first embodiment of the invention. As shown in Fig. 1, in case a base station and a mobile station communicates with each other, the base

10 station determines a transmission power bit from a radio wave received from the mobile station (S101), inserts the transmission power control bit in a transmission signal, and transmits the resulting signal to the mobile station. The mobile station receives the signal transmitted from the base station, extracts the transmission power bit (S203) and controls its variable power amplification unit according to the transmission power control bit and the states of the local station and the distant station detected in Step 202 (S205).

In Step S205, the mobile station can modify the control
20 ratio of the variable power amplification unit according to the states of the local station and the distant station. For example, the mobile station detects the absolute value of transmission power of the local station in Step 202 and increases the control ratio of a former stage variable power amplification unit
25 constituting the variable power amplification unit in proportion

to the absolute value of transmission power of the local station
in Step S205. In case the variable power amplification unit
is an active element, the smaller the input noise is, the more
the output noise of the active element suffers from the noise
5 index. Thus, by increasing the control ratio of the former stage
variable power amplifier, it is possible to increase the value
of transmission power to be input to a subsequent stage variable
power amplifier. This approach improves the carrier-to-noise
ratio (C/N) over the related art case where the control ratio
10 is fixed.

Fig. 2 shows an example of controlling the variable power
amplification unit (case 1). The transmission power is
represented as $P[\text{dBm}]$, the transmission power control volume
as $PC[\text{dB}]$, the control ratio of the former variable power
15 amplifier (former stage GCA) as $K1$, the control volume of the
former stage variable power amplifier (former stage GCA) in
 $PC1[\text{dB}]$, the control ratio of the subsequent stage variable power
amplifier (subsequent stage GCA) as $K2$ and the control volume
of the subsequent stage variable power amplifier (subsequent
20 stage GCA) as $PC2[\text{dB}]$. The control volume of former
stage GCA $PC1$ and the control volume of subsequent stage GCA
are represented as follows:

$$PC1 = K1 / (K1+K2) \cdot PC$$

$$PC2 = K2 / (K1+K2) \cdot PC$$

25 As shown in Fig. 2, the control ratio of the former stage

GCA K1 is increased when the absolute value of transmission power P is small and the control ratio of the subsequent stage GCA K2 is increased when the absolute value of transmission power P is large (series control). In the intermediate control area where control via the former stage GCA is switched over to control via the subsequent stage GCA (parallel control), continuous switchover of control is made possible by arranging so that the sum of the control ratios of the former stage GCA and the subsequent stage GCA may be equal to 1.

In Step 202, the variation volume and the variation velocity of the transmission power of the local station are detected. In Step 205, the greater the variation volume is and the higher the variation velocity of the transmission power of the local station is, the control ratio of the variable power amplifier that has the higher control sensitivity is increased. In Step 205, in case sudden control of the transmission power in the mobile station is desired, the mobile station increases the control ratio of the variable power amplifier that has the higher control sensitivity, and in case gradual control of the transmission power in the mobile station is desired, the mobile station increases the control ratio of the variable power amplifier that has the lower control sensitivity. The variable power amplifier that has the higher control sensitivity provides large control volume and high follow-up ability and the variable power amplifier that has the lower control sensitivity provides

100-900-202-000

small control volume and high control accuracy. Thus, follow-up ability to allow the transmission power following a desired power is improved via transmission power control according to the invention, compared with a case where the control ratio is fixed
5 as in the related art, thereby upgrading the transmission power control accuracy. In Step S202, the mobile station detects the variation volume and the variation velocity of the transmission power of the local station based on the variation volume and the variation velocity of the received power, transmission power
10 and transmission power control bit of the distant station.

Fig. 3 shows an example of controlling variable power amplification unit (case 2). The transmission power variation volume is represented as $PD[dB]$, the transmission power control volume as $PC[dB]$, the control ratio of a variable power amplifier
15 that has the higher control sensitivity (high-sensitivity GCA) as $K1$, the control volume of the variable power amplifier that has the higher control sensitivity (high-sensitivity GCA) as $PC1[dB]$, the control ratio of a variable power amplifier that has the lower control sensitivity (low-sensitivity GCA) as $K2$,
20 and the control volume of the variable power amplifier that has the lower control sensitivity (low-sensitivity GCA) as $PC2[dB]$.

The control volume of high-sensitivity GCA $PC1$ and the control volume of low-sensitivity GCA $PC2$ are represented as follows:

25
$$PC1 = K1 / (K1+K2) \cdot PC$$

PC2 = K2 / (K1+K2) · PC

As shown in Fig. 3, the control ratio of the low-sensitivity GCA K2 is increased when the transmission power variation volume PD is small and the control ratio of the high-sensitivity GCA K1 is increased when the transmission power variation volume PD is large (series control). In the intermediate control area where control via the lower-sensitivity GCA is switched over to control via the higher-sensitivity GCA (parallel control), continuous switchover of control is made possible by arranging so that the sum of the control ratios of the preliminary GCA and the secondary GCA may be equal to 1.

As shown in an example of controlling variable power amplification unit (case 3) in Fig. 4, the variable power amplification unit may be controlled based on the transmission power variation volume and the transmission power variation velocity. In Fig. 4, the transmission power variation velocity is represented as PV[dB/s]. As shown in Fig. 4, the control ratio of the high-sensitivity GCA K1 is increased when the transmission power variation velocity PV is higher, and the control ratio of the lower-sensitivity GCA K2 is increased when the transmission power variation velocity PV is lower.

In Step S205, the mobile station may use the fuzzy inference that is based on the variation volume and variation velocity of the transmission power of the local station to determine the control ratio. Via this approach, it is possible to properly

determine the control ratio and upgrade the transmission power control accuracy.

Fig. 5 shows an example of controlling the variable power amplification unit via fuzzy inference (case 4). The 5 transmission power variation volume is represented as $PD[\text{dB}]$, the transmission power variation velocity as $PV[\text{dB}]$, the transmission power control volume as $PC[\text{dB}]$, the control amount of the variable power amplifier that has the higher control sensitivity (high-sensitivity GCA) as $PC1[\text{dB}]$, and the control 10 volume of the variable power amplifier that has the lower control sensitivity (low-sensitivity GCA) as $PC2[\text{dB}]$. Fuzzy control rules and fuzzy inference are implemented via the minimax barycenter method. That is, the membership values $\mu_{PDi}(PD)$ and $\mu_{PVi}(PV)$ of the current transmission power variation volume PD 15 and the transmission power variation velocity PV are calculated from Figs. 5A and B respectively for each control rule and the smaller value of the membership values is determined as the condition satisfying degree Wi of each control rule. Note that i represents the rule i of Table 1 and any of the integers 1 through 25 in this embodiment.

[Table 1]

Fuzzy Control Rules

| | transmission power variation amount PD | | | | |
|--|--|----|----|----|----|
| | NB | NS | ZO | PS | PB |
| | | | | | |

| | | | | | | |
|------------------------------|----|-----|-----|-----|-----|-----|
| | NB | CNB | CNB | CNB | CNB | CZO |
| transmission power variation | NS | CNB | CNB | CNB | CZO | CPB |
| velocity PV | ZO | CNB | CNB | CZO | CPB | CPB |
| | PS | CNB | CZO | CPB | CPB | CPB |
| | PB | CZO | CPB | CNB | CPB | CPB |

Next, the conclusion membership function $\mu_{Ki}(K)$ of each control rule shown in Fig. 5C is multiplied by the condition satisfying degree Wi and after the conclusion membership function 5 is corrected, the logical add function $\mu_{K^*}(K)$ of the conclusion membership function is calculated.

$$\mu_{K^*}(K) = \mu_{K1^*}(K) \cup \mu_{K2^*}(K) \cup \dots \cup \mu_{K25^*}(K)$$

$$\text{where } \mu_{Ki^*}(K) = Wi \cdot \mu_{Ki}(K) \quad (i=1-25)$$

Next, the barycenter of the logical add function $\mu_{K^*}(K)$ 10 is obtained as the weighted coefficient K^* via fuzzy inference.

$$K^* = \int K \cdot \mu_{K^*}(K) dK / \int \mu_{K^*}(K) dK$$

In Step S205, the mobile station adaptively modifies the control ratio of the variable power amplification unit according to the states of the local station and the distant station detected 15 in Step 202. In Step S205, the mobile station can adaptively correct the control ratio of the variable power amplification unit according to the temperature of the local station, power-supply voltage, transmission frequency, diffusion ratio of a transmission signal, code multiplicity of a transmission 20 signal, and peak value of the transmission signal. Thus, by adaptively controlling the control ratio so that a constant transmission power may be obtained irrespective of variations

in the temperature of the local station, power-supply voltage, sending frequency, diffusion ratio of a transmission signal, code multiplicity of a transmission signal, and peak value of the transmission signal, the output accuracy of the transmission power is upgraded compared with a case where the control ratio is not corrected as in related art applications, thereby upgrading the transmission power control accuracy.

Further, in Step S205, the mobile station can adaptively correct the transmission power according to environmental changes. Accordingly, it is possible to correct the transmission power according to the environmental changes without modifying apparatus for a new factor of environmental changes. This leads to a simplified apparatus design and lower power consumption. In order to adaptively correct a baseband signal and control signals of variable power amplification unit and power amplifiers as the adaptive control of transmission power, the coefficient of a digital filter provided in the preliminary stage of the digital-to-analog converter (DAC) for generating these signals is modified.

In Step S205, the mobile station controls a plurality of variable power amplifiers having different control sensitivities. In Step 205, the mobile station can set the control ratios of the variable power amplifiers having different control sensitivities to proper values in order to upgrade the linearity of the control characteristics, thus upgrading the

transmission power control accuracy.

Fig. 6 shows an example of controlling variable power amplification unit (case 5). The output power is represented as P , the control sensitivity as ΔP , the control voltage as VGC ,
5 the output power of the first variable power amplifier as P_1 ,
the control sensitivity of the first variable power amplifier as ΔP_1 , the output power of the second variable power amplifier as P_2 , and the control sensitivity of the second variable power amplifier as ΔP_2 . As shown in Figs. 6A-6C, among the control
10 characteristics of the first variable power amplifier (Fig. 6A), the output power P_1 has a substantially linear characteristic except where the control voltage VGC falls within the range of 1 to 2[V]. Among the control characteristics of the second variable power amplifier (Fig. 6B), the output power P_2 has a
15 substantially linear characteristic where the control voltage VGC falls within the range of 1 to 2[V]. Thus, by selecting the first variable power amplifier where the control voltage is below 1[V] and above 2[V] and selecting the second variable power amplifier where the control voltage is within the range of 1[V] to 2[V], a linear characteristic is obtained via the
20 first and the second variable power amplifiers (Fig. 6C).

Next, the mobile station inserts the transmission power control bit determined in Step 201 in a transmission signal and transmits the resulting signal to the base station. The base
25 station receives the signal transmitted from the mobile station,

extracts the transmission power bit (S103) and controls its variable power amplification unit according to the states of the local station and the distant station detected in Step S102 (S105). Processing in Steps S102, S105 is the same as that in 5 Steps in S202, S205, thus upgrading the transmission power control accuracy and allowing a simplified apparatus design and lower power consumption.

While the foregoing description covers transmission power control, it is also applicable to received power control.

10 (Embodiment 2)

Fig. 1 is a flowchart showing the procedure of the transmission power control method according to second embodiment of the invention. As shown in Fig. 1, in case a base station and a mobile station communicates with each other, the base 15 station determines a transmission power bit from a radio wave received from the mobile station (S101), inserts the transmission power control bit in a transmission signal, and transmits the resulting signal to the mobile station. The mobile station receives the signal transmitted from the base station, extracts 20 the transmission power bit (S203) and controls its variable power amplification unit according to the transmission power control bit and the states of the local station and the distant station detected in Step 202 (S204).

In Step S204, the mobile station can modify the control 25 ratio of voltage control unit according to the states of the

local station and the distant station. For example, the mobile station detects the absolute value and the power-supply voltage of transmission power of the local station in Step 202. The mobile station increases the control ratio of voltage control unit for correcting the collector voltage of the power amplifier in proportion to the absolute value of transmission power of the local station and the power-supply voltage in Step 204. This enhances the efficiency and stability of the power amplifier, thus reducing the power consumption and upgrading the transmission power control accuracy, compared with a case where the control ratio is fixed as in related art applications. In case bias control is made on the power amplifier, the collector voltage or base voltage is controlled for reducing a consumption current. However, in case bias control is dedicated to control of the collector voltage or base voltage, variation in the transmission power or power-supply voltage invites various characteristics such as increased co-channel leak power, lower stability and reduced gain. In case the transmission power varies in a wide range such as in the CDMA system, fixing the bias voltage results in a noticeable difference between characteristics at the upper limit and the lower limit of the transmission power. By modifying the control ratio of the collector voltage control and the base voltage control according to variations in the transmission power as in this embodiment, it is possible to obtain stable characteristics over the entire

range of the transmission power.

Fig. 7 shows an example of a controlling voltage control unit (case 1). The transmission power is represented as $P[\text{dB}]$, the voltage control volume as $VC[\text{dB}]$, a control ratio of a voltage controller for controlling the collector voltage as $K1$, a control volume of the voltage controller for controlling a collector voltage as $VC1[\text{dB}]$, a control ratio of a voltage controller for controlling the base voltage as $K2$, and the control volume of a voltage controller for controlling a base voltage as $VC2[\text{dB}]$.

The control volume for controlling the collector voltage $VC1$ and the control volume for controlling the base voltage $VC2$ are represented as follows:

$$VC1 = K1 / (K1+K2) \cdot VC$$

$$VC2 = K2 / (K1+K2) \cdot VC$$

As shown in Fig. 7, the control ratio of the voltage controller for controlling the collector voltage is increased when the absolute value of transmission power is small and the control ratio of the voltage controller for controlling the base voltage is increased when the absolute value of transmission power is large (series control). In the intermediate control area where collector voltage control is switched over to base voltage control (parallel control), continuous switchover of control is made possible by arranging so that the sum of the control ratios of collector voltage control and base voltage control may be equal to 1. In general, the collector voltage

is generated by a DC/DC converter. Thus, Fig. 7 shows a control example where the usage ratio of the converter can be reduced when the consumption current is larger.

As in the example of controlling voltage control unit (case 5 2) shown in Fig. 8, the voltage control unit may be controlled based on the absolute value of transmission power and the power-supply voltage. In Fig. 8, the power-supply voltage is represented as $V[V]$. As shown in Fig. 8, the control ratio of the voltage controller for controlling the collector voltage 10 is increased when the power-supply voltage is higher and the control ratio of the voltage controller for controlling the base voltage is increased when the power-supply voltage is smaller. In general, the smaller the difference between the collector voltage and the base voltage of a power amplifier is, the less 15 stable the power amplifier becomes. Thus, Fig. 8 shows a control example where the collector voltage can be increased.

In Step S204, the mobile station may determine the control ratio by using fuzzy inference that is based on the absolute value of transmission power and the power-supply voltage of the 20 local station detected in Step S202. Via this approach, it is possible to properly determine the control ratio, thus reducing the power consumption and upgrading the transmission power control accuracy.

Figs. 9A-9C shows an example of controlling voltage control 25 unit (case 3). The transmission power is represented as $P[dB]$,

the power-supply voltage as $V[V]$, the voltage control volume as $VC[dB]$, the control ratio of the voltage controller for controlling the collector voltage as $K1$, the control volume of the voltage controller for controlling the collector voltage as $VC1[dB]$, the control ratio of the voltage controller for controlling the base voltage as $K2$, and the control volume of the voltage controller for controlling the base voltage as $VC2[dB]$. Fuzzy control rules and fuzzy inference are implemented via the minimax barycenter method. That is, the membership values $\mu_{PDi}(P)$ and $\mu_{Vi}(V)$ of the current transmission power P and the power-supply voltage V are calculated from Figs. 9A and 9B respectively for each control rule and the smaller value of the membership values is determined as the condition satisfying degree W_{i0} of each control rule. Note that i represents the rule i of Table 2 and any of the integers 1 through 25 in this embodiment.

[Table 2]

Fuzzy Control Rules

| | | transmission power P | | | | |
|------------------------|----|----------------------|-----|-----|-----|-----|
| | | NB | NS | ZO | PS | PB |
| power-supply voltage V | NB | CNB | CNB | CNB | CZO | |
| | NS | CNB | CNB | CNB | CZO | CPB |
| | ZO | CNB | CNB | CZO | CPB | CPB |
| | PS | CNB | CZO | CPB | CPB | CPB |
| | PB | CZO | CPB | CNB | CPB | CPB |

20

Next, the conclusion membership function $\mu_{K1}(K)$ of each

control rule shown in Fig. 9 (c) is multiplied by the condition satisfying degree W_i and after the conclusion membership function is corrected, the logical add function $\mu K^*(K)$ of the conclusion membership function is calculated.

5 $\mu K^*(K) = \mu K_1^*(K) \cup \mu K_2^*(K) \cup \dots \cup \mu K_{25}^*(K)$

where $\mu K_i^*(K) = W_i \cdot \mu K_i(K) \quad (i=1-25)$

Next, the weight center of the logical add function $\mu K^*(K)$ is obtained as the weighted coefficient K^* via fuzzy inference.

$$K^* = \int K \cdot \mu K^*(K) dK / \int \mu K^*(K) dK$$

10 In Step S204, the mobile station adaptively modifies the control ratio of the voltage control unit according to the states of the local station and the distant station detected in Step 202. In Step S204, the mobile station can adaptively correct the control ratio of the voltage control unit according to the 15 temperature of the local station, power-supply voltage, transmission frequency, diffusion ratio of a transmission signal, code multiplicity of a transmission signal, and peak value of the transmission signal. Thus, by adaptively controlling the control ratio so that a constant transmission power may be 20 obtained irrespective of variations in the temperature of the local station, power-supply voltage, transmission frequency, diffusion ratio of a transmission signal, code multiplicity of a transmission signal, and peak value of the transmission signal, the output accuracy of the transmission power is upgraded 25 compared with a case where the control ratio is not corrected

as in related art applications, thereby upgrading the transmission power control accuracy.

In Step S204, the mobile station can adaptively correct the transmission power according to environmental changes.

5 Accordingly, it is possible to correct the transmission power according to the environmental changes without modifying apparatus for a new factor of environmental changes. This leads to a simplified apparatus design and lower power consumption.

10 In order to adaptively correct a baseband signal and control signals of variable power amplification unit and power amplifiers as the adaptive control of transmission power, the coefficient of a digital filter provided in the former stage of the digital-to-analog converter (DAC) for generating these signals is modified.

15 In Step S204, the mobile station controls a plurality of voltage controllers having different control sensitivities. In Step 204, the mobile station can set the control ratios of the voltage controllers having different control sensitivities to proper values in order to upgrade the linearity of the control 20 characteristics, thus upgrading the transmission power control accuracy.

Fig. 10 shows an example of controlling voltage control unit (case 4). The output voltage is represented as P , the control sensitivity as ΔP , the power-supply voltage as V , the 25 output voltage of the first voltage controller as P_1 , the control

TOE791-22764860

sensitivity of the first voltage controller as ΔP_1 , the output voltage of the second voltage controller as P_2 , and the control sensitivity of the second voltage controller as ΔP_2 . As shown in Figs. 10A-10B, among the control characteristics of the first 5 voltage controller (Fig. 10A), the output voltage P_1 has a substantially linear characteristic except where the power-supply voltage V falls within the range of 1 to 2[V]. Among the control characteristics of the second voltage controller (Fig. 10B), the output voltage P_2 has a substantially linear 10 characteristic where the power-supply voltage V falls within the range of 1 to 2[V]. Thus, by selecting the first voltage controller where the power-supply voltage is below 1[V] and above 2[V] and selecting the second voltage controller where the power-supply voltage is within the range of 1[V] to 2[V], a linear 15 characteristic is obtained via the first and the second voltage controllers (Fig. 10C).

Next, the mobile station inserts the transmission power control bit determined in Step 201 in a transmission signal and transmits the resulting signal to the base station. The base 20 station receives the signal transmitted from the mobile station, extracts the transmission power bit (S103) and controls its variable power amplification unit according to the states of the local station and the distant station detected in Step S102 (S104). Processing in Steps S102, S104 is the same as that in 25 Steps in S202, S204, thus upgrading the transmission power

control accuracy and allowing a simplified apparatus design and lower power consumption.

While the foregoing description covers transmission power control, it is also applicable to received power control.

5 (Embodiment 3)

Fig. 11 is a block diagram showing an embodiment of radio communications apparatus according to the invention. In Fig. 11, the numeral 11 represents an antenna, 12 a transmit/receive separator, 13 a power amplifier, 14 a first variable power amplifier, 15 a second variable power amplifier, 16 a modulator, 17 a digital-to-analog converter (DAC), 18 variable power amplification control unit, 19 first voltage controller, 20 second voltage controller, 21 control unit for controlling voltage controllers, 22 a baseband signal processor, 23 state detection unit, 24 a demodulator, 25 a radio transmitter, and 26 a radio receiver.

In case the radio communications apparatus shown in Fig. 11, the baseband signal processor 22 determines a transmission power bit received from the base station and inserts the 20 transmission power control bit in a transmission signal. The transmit signal is converted to an analog signal by the DAC 17, frequency-converted to a signal in the IF band by the modulator 16, converted to a signal in the RD band by the radio transmitter 25, then sent to the base station from the antenna 11 via the 25 transmit/receive separator 12.

The signal transmitted from the mobile station is received by the antenna 11. The received signal is input to the radio receiver 26 via the transmit/receive separator 12. The radio signal is frequency-converted to a signal in the IF band by the 5 radio receiver 26 and converted to a baseband signal by the demodulator 24.

The baseband signal processor 22 extracts a transmission power control bit from the baseband signal output from the demodulator 24. The state detection unit 23 detects the states 10 of the base station and the local station based on the variation volume and the variation velocity of the receiving power, transmission power and transmission power control bit of the base station and the local station, the variation volume and the variation velocity output from the baseband signal processor 15 22.

The variable power amplification control unit 18 controls the first and the second variable power amplifiers 14, 15 and DAC 17 according to the extracted transmission power control bit and the detected states. The variable power amplification 20 control unit 18 controls the first and the second variable power amplifiers 14, 15 based on the transmission power control shown in the first embodiment. The variable power amplification control unit 18 controls the gain of the DAC 17 to arrange the dynamic range and linearity of the baseband signal obtained 25 before modulation.

100-2264860

The control unit for controlling voltage controllers 21
controls the first and the second voltage controllers 19 and
20. The control unit for controlling voltage controllers 21
controls the first and the second voltage controllers 19 and,
5 20 based on the transmission power control shown in second
embodiment.

Thus, accuracy of follow-up ability of the transmission
power to a desired power is improved by the radio communications
apparatus according to the embodiments of the invention, thus
10 upgrading the transmission power control accuracy. This also
minimizes the necessary transmission power and assures lower
power consumption and smaller size of apparatus.

As mentioned earlier, accuracy of follow-up ability of
the transmission power to a desired power is improved by the
15 invention, thus upgrading the transmission power control
accuracy. This also minimizes the necessary transmission power
and assures lower power consumption and smaller size of
apparatus.